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ABSTRACT

Clarifying the influences determining how and to what extent highly qualified personnel are employed, this study discusses those sorts of economic and technological advances affecting employment potentials. Two main trends in scientific and technological progress--computerized industries and the high science-content of production--have so increased the amount of technological equipment available per worker and restructured the economy based on technological innovation that they have altered the occupations and skill requirements of the labor market. A statistical analysis of the distribution of scientific and technical manpower in industry shows that the training of technicians and scientists leads in the long run to a qualitative transformation of production and the system of production, leading in turn to increased emphasis on vocational and professional education as means of increased worker proficiency. As production becomes increasingly science-intensive, education is becoming one of the most important components of production. In the future, jobs will require breadth of qualifications and experience, regular re-training, and a high level of general education--all gained from an education restructred to include scientific, vocational, and general education. However, making truly effective use of highly qualified specialists depends upon the extent to which economic and technological policy is directed towards satisfying social needs. (JW)

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SCIENTIFIC AND TECHNOLOGICAL PROGRESS AND JOB QUALIFICATION

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According to world-wide experience, job qualification has become one of the most important factors in modern economic development and in the speeding up of scientific and technological progress. In this connection, importance is being assumed by analysis of the objective relationships between the basic indicators of scientific and technological progress and the job qualification of the labour force, and by the question of the effect of scientific and technological progress on change in the occupational and skill structure of the labour force and in the actual essence of job qualification.

The problem of qualification has both an economic and a social aspect. In present-day circumstances, a high standard of general and vocational education has become a social demand for broad sectors of the public. In the majority of industrialised and developing countries, there has been a considerable extension over the past decade of the system of higher education. Meanwhile, by no means all graduates of universities and other institutions of higher education are able to find work in their area of specialisation or merely something commensurate with their qualifications. The problem of job placement of young specialists and of unemployment among highly qualified people has become very acute for a number of countries. It is hence exceedingly urgent to clarify the basic factors determining the scope for and scale of utilisation of highly qualified personnel.

Alongside the objective economic development factors determining the demand for highly qualified specialists, the various options regarding the science and technology policies of particular countries have a considerable effect on the formation of demand. The events of the 1970s, coupled with amplification of the adverse consequences of scientific and technological development (the energy crisis, aggravation of ecological problems, the continuing arms race, and the ever-present danger of thermonuclear disaster), have raised the issue of a shift in basic priorities and of the essence of science and technology policy. In this connection, it is becoming urgent to investigate the effect of changes in the aims and trends of science and technology policy on the character of the employment of highly qualified specialists.

This paper sets out to review a number of aspects of the above issues.

1. Objective relationships between scientific and technological progress and job qualification

The establishment of quantitative relationships between scientific and technological progress and job qualification is a highly complex matter. This is due to the fact that scientific and technological progress represents a whole array of different processes determined by not one but many parameters. In turn, the change regarding qualification in the broad sense of the word is also not a single clear-cut process. It includes change in the occupational and skill structure of the labour force, namely in the quantitative correlations between the different categories of that force; change in the level of qualification, namely a rise in the qualitative indices of the general educational and special training of the various labour-force categories.

In this connection, it seems reasonable to make use of the following method for analysing the relationships between scientific and technological progress and job qualification:

- Identification of the basic trends in scientific and technological progress and adoption of a series of indicators designating these trends;
- Establishment of quantitative relationships between these indicators of scientific and technological progress and the indicators denoting change in the job qualification of the labour force.

(a) Trends in scientific and technological progress

With regard to basic trends in scientific and technological progress, it should be noted that what is involved is not merely an enumeration of the main trends in the development of science and technology, but the more general patterns connected with the present stage of development of productive forces.

It is generally recognised that science has become a direct productive force, and the process of revolutionary re-organisation of production under the impact of science is now an unbroken one and has spread to all areas of the economy. One indicator of the extended scale of scientific research is the increased expenditure on scientific research in all industrialised countries.

In the USSR, according to the data of the Central Statistical Office, total expenditure on scientific research in 1975 amounted to 17.4 billion roubles, or 4.8 per cent of national income (1). In the United States of America, expenditure on research and development was $34.3 billion, or

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(1) Calculated from data of the USSR Central Statistical Office. Narodnoe hozjajstvo SSSR v 1975 g. (The national economy of the USSR in 1975).

2.4 per cent of gross national product. In Japan, such expenditure had by 1973 risen to 1.9 per cent of gross national product, the corresponding percentages being 2.1 for the Federal Republic of Germany, 2.3 for the United Kingdom, and 1.8 for France. (1)

The constantly diminishing amount of time taken to put new scientific discoveries and inventions into practical effect, with the greatly extended research effort, has called for a particularly rapid growth in expenditure on experimental design work and the adoption of new discoveries in mass production. This field of activity - providing a link between science and production - plays a decisive part in stepping up the pace of technological progress. It is no accident that expenditure on experimental design work and application considerably exceeds expenditure on scientific research and in some cases increases faster.

The foregoing outlays by no means exhaust all sums earmarked for devising, mass producing and marketing new products. Outlays on the technological re-orientation of enterprises, on the manufacture of new products and on marketing exceed the total amount spent on research and experimental designing. Thus the total outlay on devising a new product is rather like an iceberg, expenditure on research and development being merely the visible part. In this matter we must clearly to some extent seek the clue to the well-known paradox of the lack of correlation between the share of expenditure on research and development in relation to gross national product, and the pace of economic growth.

It seems important that there should be a specified allocation of expenditure to research and development. Only a relatively small proportion of such expenditure goes to the development of new production methods and technology. The lion's share of spending is earmarked for basically new products. "New products", as a concept, covers those products whose advent hinges on the application of recent scientific discoveries and inventions without which such products could not materialise. This is what chiefly distinguishes new products from former products that have been modified and improved. A decrease in the time taken to adopt new products ultimately speeds up renewal of the production structure.

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(1) Statistical Abstract of the United States. Unesco Statistical Yearbook, 1975.

Rapid change in the production structure and in the character of what is produced, together with the constant process of adopting new products stemming from recent achievements of science and technology, lends ever greater significance to such an important factor of modern economic life as product obsolescence. This factor affects a broad range of economic issues, such as economic growth, value formation and new forms of competition.

Scientific and technological progress affects competition in world markets. Although formerly the basic factor in the competitiveness of a particular firm's article was the cost price and the day was won by the firm producing its articles with the lowest outlays, it is now the case that a new factor also comes into play, and that is the novelty of the product, determining whether or not the article is competitive. The more technologically advanced the product is and the greater the new scientific discovery component, the more easily it will conquer the market. The degree of product novelty depends to a significant extent on the scale of development of scientific research work in industry. (1)

The new character of competition in world markets acts as a goad to the structural re-organisation of industrial production and to the emergence and development of new branches and industries bound up with the basic trends in scientific and technological progress. This process is a constant one: a distinct kind of "bushing" of the branch takes place within which new industries are separated out. As a rule, the majority of "growth points" are to be found in new branches (electronic engineering, computer science, polymer chemistry, the aerospace industry, instrument making) situated in the van of technological progress.

Science has become a potent stimulant for economic development and a chief factor of higher labour productivity, substantial changes having taken place in the sources of such increased productivity. This increase is nowadays accountable not so much in terms of a quantitative rise in production (output units per man-hour) as in terms of a qualitative change in the product itself with the advent of fundamentally new articles.

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(1) Education, Income and Human Capital. Ed. by W. Hansen. New York, London, 1970.

The quantitative aspect of higher labour productivity is mainly associated with a change in the technological basis of production, with the adoption of more productive equipment, and with the development of mechanised and automated production processes. During the 1971-1975 period, 732,000 units of production equipment were modernised in the USSR, and the number of transfer lines in industry rose from 5,981 in 1965 to 17,072 in 1975. The electrical power available per worker in industry was 70 per cent at the end of the ten-year period, and the development of automatic control systems is proceeding apace. In the 1966-1970 period, 414 automated control systems were established, the corresponding figure for 1971-1975 being 2,364. (1)

The qualitative aspect of increased labour productivity hinges chiefly on the larger scale of scientific research and of experimental design work in industry, resulting in new types of goods, and on the greater science content of production. In the 1966-1970 period, 8,400 items of new industrial goods were adopted and brought into series production in the USSR, while the corresponding number of items for 1971-1975 was 16,500. (2) Analysis of these two basic aspects of higher labour productivity points to the main trends in scientific and technological progress. The first trend appears in the increased amount of technological equipment available per worker, and particularly in the process of "cybernetization", including not only the automation of production but the widespread introduction of automatic control systems in all spheres of economic life. The second trend is associated with the higher science content of production, resulting in faster processes of structural re-organisation of the economy, in the establishment of new branches and in the output of fundamentally new types of goods incorporating the latest scientific discoveries and inventions.

Both these trends exert a far-reaching effect on change in the occupational and skill structure of the labour force and on its standard of proficiency.

"Cybernetization" of the economy. This trend has greatly increased the demand for specialists able to install, serve and repair computer equipment.

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(1) USSR Central Statistical Office. Narodnoe hozjajstvo SSSR v 1975 g. (The national economy of the USSR in 1975), pp.172-175.

(2) op.cit., p.171

The new specialized lines associated with modern computer technology require, as a rule, a high standard of special training and general education. At the same time, the "cybernetization" of the economy changes in many respects the content of a number of traditional trades and professions and correspondingly pushes up requirements regarding standards of proficiency.

Thus the adoption of automatic control systems for production leads to re-organisation of the structure of management and a change in the functions of managerial personnel.

The formerly prevalent departmental conception in management (the presence of mutually isolated divisions - such as research, production, marketing and finance - with their own criteria and evaluations) is being superseded by the systems approach to management of a corporation whereby it is regarded as a single organism the functioning of each part of which is closely bound up with the remaining parts. Overall criteria and standards apply here, covering the entire process from receipt of the order to delivery of the finished product. The systems approach to corporate management is based on a developed information network integrated into a single system. Such integration is possible only with computerisation.

The re-organisation of corporate management on the basis of the systems principle does away with many intermediate management units, as a result of which some categories of middle-management are "washed out". The functions of data collection and in part, analysis are switched direct to computers.

At the same time, big changes are also taking place in senior management. The computerised integration of information makes the corporation more manageable and rapidly responsive to command from above. Extensive opportunities are opened up for analysing the activity of the corporation and working out programmes for its development.

There is a concurrent sharp rise in the responsibility of top management for decision-making. The computer cannot replace the manager; it merely provides him with the best possible opportunity for a creative approach to management. But the level at which such leadership is provided depends on the intellectual capacities and the proficiency of managerial personnel.

In industry the development of automation of production processes is associated with considerable re-organisation of the structure of employment. Switching of the vast majority of production functions from man to the machine results in a sharp decrease in the proportion of personnel directly involved

in the production process. The emphasis in the work performed is switched from the control of machine-tools and devices to the technical servicing of automatic units, covering the elaboration of programmes and technological regimes and repair and adjustment operations. Hence a sharp increase in the proportion of engineering and technology services in highly automated enterprises.

Investigation of the effect of the level of automation on the occupational structure of the worker complement, covering eight enterprises of the USSR machine-building industry, enables the following comparisons to be made. (1) :

	Proportion of equipment			Machine operators	Adjusters
Enterprise	automatic	semi-automatic	other	(as percentage of total worker complement)	
1	100	-	-	7.6	51.0
2	100	-	-	19.0	40.0
3	-	100	-	57.8	11.8
4	8	82	10	52.2	11.5
5	-	60	40	62.4	12.7
6	-	25	75	80.4	7.0
7	-	-	100	76.0	-
8	-	-	100	84.0	-

The higher the level of automation, the greater will be the proportion of adjusters and the smaller the share of machine operators in the total worker complement.

The level of automation also has a direct effect on personnel proficiency standards. This is borne out by the following data on the USSR machine-building industry. (2)

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(1) A. Osipov, I. Kovalenko, E. Petrov, Sovetskij rabočij i avtomatisačija (The Soviet worker and automation) Moscow, 1960, p.88

(2) op. cit., pp.99-112

Proportion of equipment				Average proficiency pay grade		
Enterprise	Automatic	Semi-automatic	others	Machine operators	Repairmen	All workers
1	100	-	-	5.0	6.8	6.6
2	100	-	-	5.0	6.6	5.9
3	-	100	-	4.7	6.2	6.2
4	8	82	10	3.9	5.7	4.5
5	-	60	40	4.0	5.3	4.3
6	-	25	75	3.7	5.6	4.0
7	-	-	100	3.6	4.7	3.7
8	-	-	100	3.6	3.8	3.4

The higher the level of automation, the correspondingly higher will be the average proficiency pay grade (on the eight-grade pay scale) of workers.

The rise in the level of automation of production is fairly closely matched by the tendency for the proportion of workers to decline and the proportion of engineering and technical personnel and other employees in the total employment figure to go up. Alongside this, another trend may be noted: the higher the level of automation, the higher the proportion of skilled workers in the total worker strength and - what is particularly important - the higher the proportion of skilled workers with complete secondary education, namely workers whose special area of proficiency demands a fair standard of general development and a sound general education. (1)

The science content of production. The influence of this factor on the occupational and skill structure of the labour force can be traced, first, in an increased proportion of personnel engaged in scientific research and experimental design work and, second, in the modified structure and functions of personnel directly engaged in production.

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(1) Profiles of Manufacturing Establishments. New York, 1968

With regard to personnel engaged in research and experimental design work, the tie-up between the scales of development of research and development and of the occupational and skill structure of employment is fairly clear. The absolute number of scientific and supporting personnel engaged in research and development virtually hinges on science and technology policy and, in particular, on the volume of expenditure in this sphere. In the main, variations are possible here in regard only to the ratio between expenditure on personnel pay and outlays on scientific and experimental equipment and between personnel pay levels in different branches.

Although the relationship between the absolute figures for the volume of expenditure on research and development and for research personnel strength is a fairly simple one, the link between their relative values is somewhat more complex: between the size of the outlay on research and development, as against volume of net sales, and the proportion of the total number of people engaged in the branch accounted for by research personnel. What is actually involved here is the effect of the scale of the development of research work on the employment structure in the branch. The proportion of research personnel cannot be fixed solely by the scale of development of research since a substantial part is played here by a number of other factors, including the efficiency of expenditure on scientific research. The general trend towards greater efficiency of social production, with the rise in expenditure on research and development, may be traced only when long periods of time are taken into consideration. Between investment in research and development and the return on it, there is a certain time lag. What is more, there exists an inter-branch link effect in that the growth of research in one branch may yield an economic effect in an associated branch.

Nevertheless, there must objectively be a fairly close relationship between the scale of research activity in industrial branches and the proportion of research and design personnel.

With regard to personnel engaged in production, the constant re-organisation of the production process, prompted by the adoption of new and, as a rule, technically more complex types of product, requires a relatively high share of technological engineers, highly qualified technicians, adjustment and repair mechanics, and other skilled workers. As a result, the level of development of research work in the branch should also have a definite

effect on the proportion of highly qualified specialists (as against the total employment figure) not engaged in research and experimental design work. This is of prime importance for estimation of the rôle of research: what is involved is not simply the local factor determining the structure of employment in a limited area, but one of the main factors of change in the occupational and skill structure of the labour force as a whole. The higher the level of research work in the branch, the greater will be the demand for scientific and technological engineering personnel, not only in the laboratory but in the actual shop section of the enterprise. The more complex assignments regarding organisation and management in branches with a large research component require a greater proportion of administrative and managerial personnel than in the case of branches whose character and production structure change slowly. Hence the relatively greater numbers of administrative and clerical personnel in branches of the former type.

To round off investigation of the effect of the two main trends in scientific and technological progress - "cybernetization" and raising of the science content of production - on the occupational and skill structure of the labour force, it should be emphasised that both these trends make for a higher general standard of proficiency. However, development of one does not automatically induce development of the other (i.e. more extensive research does not necessarily mean that there will be a higher level of automation, and vice versa). In addition, the faster the occurrence of structural changes in production, the more difficulties are encountered in the course of automating production processes. In the case of constant adoption of basically new types of product, automation of production of the initial series is greatly complicated. This applies primarily to the group of branches connected with machine-building and instrument-making.

(b) Quantitative relationships

The effect of the two foregoing basic trends of technological progress in industry on the occupational and skill structure of the labour force lends itself to quantitative estimation. This can be done by means of regression analysis. Each of the factors needs to be expressed in the form of a specific quantitative indicator, these indicators being compared with the occupational and skill composition of the labour force by branches.

What indicators can be used to denote the extent of automation at branch level or for industry as a whole? We obviously must not go by the types of machine-tools and devices since the various branches do not use

uniform equipment. At the same time, a close link is known to exist between the level of automation and such indicators as capital investment per worker and available power supply per worker. The higher the forms of automation prevalent in a particular branch of industry, the greater these indicators will be. For instance, while in the United States motor industry, where only a few production processes are automated, the annual consumption of electric power per employee in 1973 was 18,900 kwh, and investment per production worker $29,800, in branches with an uninterrupted production process, where complex automation is applied, the figures are several times higher. Thus in the United States petroleum industry they amount respectively to 167,700 kwh and $269,100.

Accordingly, when comparing the level of automation by branch, use can be made of the figures for power consumption or capital expenditure per worker. As to the level of development of scientific research work in the branch, it can be expressed in terms of the outlay on research as against the total volume of net sales. Since this is a cost indicator, it will also be fitting to use a cost indicator to designate the level of mechanisation and automation.

Let us now go straight on to clarification of the quantitative dependence of the structure of the labour force on the above factors. The most dynamic and important for the development of present-day production is the category of highly qualified specialists, including scientists and engineers, together with technicians (see Table 1).

The table shows the great unevenness in the distribution of scientific and technological engineering personnel among the branches of manufacturing industry in the United States. While in the aerospace, electrical engineering (including electronics), machine-building and chemical branches there is a plentiful supply of highly qualified manpower, in such branches as motor vehicles, metallurgy, paper and the glass and pottery industry, this supply is relatively lower, and in a number of branches of light industry - food, textiles and sewn goods - the proportion is extremely low. A feature in this respect is that the bulk of scientists and computer specialists are engaged precisely in the "science-intensive" branches spearheading technological progress. At the same time, some of these branches, with the considerable scale of development of research, are marked by a high level of mechanisation and automation. This primarily concerns the chemical and petroleum industry.

Table 1. Scientific and technical manpower in United States industry (in thousands of persons)(1)

Branch of (manufacturing industry)	Engineers	Computer specialists	Mathematicians	Physicists and chemists	Medium-range technical manpower	Share of scientific and technical manpower in total employment figure percent
Aerospace	101,04	8,47	1,14	2,18	33,79	20,7
Electrical engineering and electronics	154,84	15,15	1,02	4,14	92,73	14,1
Machine-building	103,30	28,62	0,64	2,91	62,64	10,0
Motor vehicle	30,69	3,59	0,59	0,94	17,05	5,2
Metallurgy	25,60	2,99	0,31	7,32	20,52	4,7
Metal-working	28,77	2,52	0,15	1,95	24,27	4,8
Chemicals and petroleum	41,99	5,20	0,79	36,56	53,08	13,9
Production of rubber and plastics	12,52	1,21	0,07	2,69	9,53	4,9
Paper	10,07	1,44	0,20	2,01	11,21	3,8
Wood-working	4,99	0,85	0,05	0,25	4,84	1,1
Glass and pottery	10,92	0,95	0,13	2,41	9,71	4,0
Food	10,79	2,45	0,29	6,02	14,12	2,4
Textiles	6,85	1,55	0,07	1,49	8,23	1,9
Sewn goods	2,71	0,99	0,03	0,10	1,82	0,5

(1) U.S. Census of Population, Detailed Characteristics, Washington, 1973, p. 788 - 790.

In order to establish the quantitative dependence of the share of scientific, engineering and technical manpower in the total employment figure on such factors as the degree of development of research and the level of automation and mechanisation, let us look at the multiple correlation of these indicators given in Table 2.

The linear coefficient of correlation (x) between the share of scientific and technical manpower (y) and investment per production worker (x) amounts to +0.444, while between (y) and the index for expenditure on research and development against the volume of net sales (z) it comes to +0.805.

Although each of the factors has a substantial effect on the relative scientific and technical manpower strength none dictates it entirely. On the other hand, the interaction of these factors to a considerable extent predetermines the share of such manpower in the total employment figure. The coefficient of multiple correlation between (y), (x) and (z) amounts to +0.976, and the coefficient of determination to 0.952.

Between the indices for the supply of capital per worker and the ratio of expenditure on research to net sales there exists a reciprocal, the linear correlation coefficient being -0.076.

The equation of regression looks like this:

$y = 1.330 + 0.047\ x + 1.222\ z$

(x) The linear correlation coefficient may be calculated from the equation:

$$R_{xy} = \frac{\sum x\,y - \frac{\sum x \sum y}{h}}{\sqrt{\left(\sum x^2 - \frac{(\sum x)^2}{h}\right)\left(\sum y^2 - \frac{(\sum y)^2}{h}\right)}}$$

The multiple correlation coefficient is calculated from the equation:

$$R_{y\,x\,z} = \sqrt{\frac{R^2_{yx} + R^2_{yz} - 2R_{yx} \cdot R_{yz} \cdot R_{yz}}{1 - R^2_{xz}}}$$

Table 2. Factors governing the distribution of scientific and technical manpower in in United States industry. (1)

Branch of manufacturing industry	Share of Scientific and Technical manpower in total employment figure %	Investment per production worker $000	Expenditure on research as percentage of net sales
Aerospace	20,7	43,1	16,0
Electrical engineering and electronics	14,1	33,9	7,4
Machine-building	10,0	40,6	3,8
Motor vehicle	5,2	29,8	3,5
Metallurgy	4,7	44,8	0,8
Metal-working	4,8	23,7	1,2
Chemicals	13,9	75,5	3,9
Petroleum-refining	14,2	269,1	1,0
Production of rubber and plastics	4,9	24,7	1,9
Paper	3,8	33,7	0,9
Wood-working	1,1	19,0	0,8
Glass and pottery	4,0	27,4	1,7
Food	2,4	39,4	0,5
Textiles and sewn goods	3,1	12,5	0,5

(1) Calculated from data in: U.S. Census of Population. Detailed Characteristics, 1973. Research and Development in Industry, 1972. Statistical Abstract of the United States, 1975.

Thus the relative significance of scientific and technical manpower in the total employment figure for industry depends more on the scale of development of research than on the supply of capital. This may be explained by the fact that an ever greater slice of scientists and engineers is drawn out of the direct production sphere into research, design and experimental work. Reference can further be made to a number of other less significant indicators connected with various aspects of present-day scientific and technological progress and in one way or another affecting the occupational and skill structure, such as the level of organisation and management. Furthermore, the processes of scientific and technological progress are so varied and dynamic that they cannot of course be fully covered by any stable system of indicators.

So it is with the influence of the basic trends in scientific and technological progress on change in the occupational and skill structure of the industrial work-force, particularly in such a key category as scientific and technical manpower. What is the situation, however, in other areas of the economy like transport, communication, non-industrial research, manpower training, and so on? It is reasonable to assume that in these areas the employment of engineers and scientists is ultimately determined by the foregoing trends in scientific and technological progress, and that the share of scientific and technical manpower in the total employment figure depends to a significant extent on the technological back-up of labour and the scale of development of research and experimental design work. This assumption can be checked through comparison of the corresponding figures for a number of countries.

It should be noted that comparisons of this kind are fraught with inevitable difficulties since the peculiarities of national statistics must be borne in mind. For one thing, nothing like all national statistics include data on total numbers of scientists and engineers, and even where such data do exist, difficulties arise regarding the comparability of proficiency levels.

Data for the USSR are taken from the Central Statistical Office publication on the USSR economy in 1975. (Narodnoe khozjajstvo USSR v 1975 g) As a basis for comparison with other countries, use has been made of OECD

material on the occupational structure of the labour force in 53 countries (1) and of annual Unesco publications. (2)

Since the OECD publication contains data on the numbers of engineers and natural scientists with complete higher education for 1960-1961 only, the following method was used to estimate the numerical strength of these categories in 1973:

- A calculation was made of the number of engineers and natural scientists (excluding the medical profession) trained in each country during the 1960-1973 period;
- it was assumed that about 5 per cent of the total output of engineers and scientists worked outside their subject area;
- it was assumed that some 10 per cent of engineers and scientists at work in 1960-1961 had retired by 1973;
- the numbers in the categories concerned in 1960-1961 were added to the total number of engineers and scientists trained, minus those who had retired or were working outside their subject area.

Where national statistics do not single out engineers and scientists with complete higher education, a more indirect method was needed:

- From Unesco data on the proportion of the population aged over 25 with higher education and on the relative size of the category of specialists (or "professionals") among the economically active population, the proportion of the total number of specialists in the country accounted for by specialists with higher education was calculated;
- this indicator, with a certain adjustment, was used for the category of engineers and scientists.

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(1) Statistics of the Occupational Structure of the Labour Force, OECD, Paris, 1969

(2) Unesco Statistical Yearbook, 1975.

The data obtained for the numbers of engineers and natural scientists with higher education provide an estimate and do not lay claim to a high degree of accuracy. Account is not taken, for instance, of the brain drain. What is significant for this investigation, however, is not the absolute but the relative figures reflecting the size of those categories as against the total employment figure for the economy. (See Table 3).

For estimation of machinery available to labour, the indicator used was the volume of capital investment per employee, expressed in United States dollars. Calculations were based on USSR Central Statistical Office data, according to which capital investment in the USSR for 1975 was slightly higher than in the United States, (1) and on United Nations statistics. (2) (see Table 4)

For estimation of the development of scientific and experimental design work in each country, use was made of the ratio of expenditure on research and development to gross national product. (3)

As a result, the following comparison was obtained of the relative numbers of engineers and scientists and of scientific and technological progress indices for the seventeen countries. (see Table 5).

The coefficient of linear correlation between the index of machinery available to labour (x) and the proportion of engineers and scientists (y) amounts to + 0.705. The coefficient of linear correlation between the index of the share of expenditure on research and development in gross national product (z) and the proportion of engineers and scientists (y) is + 0.792. The coefficient of linear correlation between (x) and (z) comes to + 0.403. The coefficient of multiple correlation Ryxz = + 0.897.

Regression equation:

$y = 0.138 + 0.419\ x + 0.524\ z$

Coefficient of determination: 0.805.

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(1) USSR Central Statistical Office. Narodnoe hozjajstvo SSSR v 1975 g. (The national economy of the USSR in 1975), p.121.

(2) Monthly Bulletin of Statistics, 1977, No.9.

(3) Unesco Statistical Yearbook, 1975.

Table 3. Estimated share of scientists and engineers in total employment figure

Country	Scientists and engineers with higher education (000)	Total employment figure (000 000)	Share of scientists and engineers in total employment figure (%)
USSR	4 906	117,4	4,1
USA	1 670	84,4	2,0
Japan	738	52,3	1,4
Germany (Fed. Rep.)	500	26,2	1,9
France	420	20,9	2,0
United Kingdom	400	24,6	1,6
Canada	250	8,7	2,9
Netherlands	120	4,5	2,7
Belgium	90	3,7	2,4
Sweden	80	3,9	2,1
Norway	58	1,7	3,4
Turkey	36	15,8	0,2
Austria	35	3,0	1,2
Denmark	30	2,4	1,3
Greece	25	3,2	0,8
Finland	20	2,2	0,9
Portugal	17	3,4	0,5

Table 4. Capital investment per employee

Country	Capital investment ($ billions)	Size of labour force (millions)	Capital investment per employee ($ thousands)
USSR	over 246	117,4	over 2,1
USA	235,8	84,4	2,79
Japan	150,9	52,3	2,88
Germany (Fed. Rep.)	86,7	26,2	3,30
France	59,7	20,9	2,85
United Kingdom	33,0	24,6	1,34
Canada	33,3	8,7	3,82
Netherlands	13,6	4,5	3,02
Belgium	9,6	3,7	2,59
Sweden	11,0	3,9	2,80
Norway	5,7	1,7	3,35
Turkey	3,8	15,8	0,24
Austria	7,5	3,0	2,50
Denmark	6,2	2,4	2,60
Greece	3,5	3,2	1,09
Finland	4,7	2,2	2,17
Portugal	2,2	3,4	0,64

Table 5. Relative numbers of engineers and scientists and of scientific and technological progress indices

Country	Engineers and scientists as percentage of labour force	Capital investment per employee ($ thousands)	Expenditure on R & D as % of GNP
USSR	4,1	over 2,1	4,8(*)
USA	2,0	2,79	2,3
Japan	1,4	2,88	1,9
Germany (Fed. Rep.)	1,9	3,30	2,1
France	2,0	2,85	1,8
United Kingdom	1,6	1,34	2,3
Canada	2,9	3,82	1,2
Netherlands	2,7	3,02	2,3
Belgium	2,4	2,59	1,2
Sweden	2,1	2,80	1,6
Norway	3,4	3,35	1,2
Turkey	0,2	0,24	0,3
Austria	1,2	2,50	0,5
Denmark	1,3	2,60	1,0
Greece	0,8	1,09	0,2
Finland	0,9	2,17	0,9
Portugal	0,5	0,64	0,3

(*) In the USSR, the amount spent on science (17.5 billion roubles) as a proportion of national income (362.8 billion roubles) in 1975.

USSR Central Statistical Office. Narodnoe hozjajstvo SSSR v 1975 g. (The national economy of the USSR in 1975), pp.563, 744

Thus the foregoing trends in scientific and technological progress have a substantial effect on the employment of scientific and engineering personnel both in industry and in other areas of the economy.

The following basic objective relationships can be singled out as regards appropriations for scientific and technological progress, first, between expenditure on research and development and expenditure on manpower training; second, between investment in new technology and expenditure on manpower training.

Scientific research cannot be extended without increased spending on the training of scientific and technical manpower. This is the most obvious and superficial link. But there are deeper links as well; expenditure on research leads in the long run to a qualitative transformation of production (with the advent of new technology and new products). This in turn calls for a higher standard of proficiency, which is bound up with increased expenditure on vocational and professional education. Thus more budgetary spending on research and development prompts a rise in expenditure on manpower training.

It can be established that the dynamics of expenditure on manpower training is also dependent on such an important factor as budgetary spending on new production technology - the most effective and fast-growing sector of capital investment as a whole. In particular, there is an indisputable link between capital investment in new technology and equipment and expenditure on vocational and professional training in industry.

Part of the capital investment in new technology and equipment is used for building new enterprises and extending old ones. This results in the creation of new jobs, which directly involves expenditure on the vocational training of workers for them. A further part of capital investment in new technology is spent on re-equipping existing work spaces with more advanced technology. Such re-equipment requires a certain amount of expenditure on retraining the existing work-force.

It is a known fact that as the technological standard of production rises, there is an increase in the cost of equipping each work space. This trend is also observed with regard to expenditure on the vocational training of workers: the more complex the technology, the higher will be the level of proficiency of the worker and the expenditure on his vocational training.

The requisite outlays for improving the standard of proficiency include, apart from direct spending on vocational training, expenditure on raising the general standard of education. There is accordingly also an objective link between capital investment in new technology and general expenditure on education.

The establishment of objective relationships between equipment available to labour, level of development of research, and proportion of engineers and scientists is of direct significance when it comes to planning the training of scientific and technical manpower. Plans for the training of engineers and scientists should be closely tied in with plans for the furthering of research and development and with investment plans. Where there is no such planning, dangerous imbalances may emerge which impair the effectiveness of employing highly qualified specialists.

These relationships permit an approach from new positions to the issue of the economic efficiency of raising the job qualification of labour. Outlays on higher proficiency may yield an economic effect not in themselves but only where they are intrinsically bound up with the adoption of new production methods and technology and with a switch to new types of product embodying the achievements of science.

Investigation of the problem of the effectiveness of raising job qualification may produce better results if more attention is given to analysing the necessary conditions for the efficient use of skilled manpower. There is obviously need for a complex approach viewing increased proficiency as an integral part of technological progress in its effect on economic growth.

This problem comes in for a great deal of attention in the work of economists, and it is investigated mainly by means of economic growth models incorporating the proficiency or education factor (1) Underlying the models, as a rule, is the production function.

The production function is a macro-economic abstraction and its weak point is the excessive degree of abstraction, which may distort the real substance of the process subjected to modelling. If the proficiency factor is introduced into the production function as an independent variable, aside from capital available to labour and the level of research, the production function describes the economy as a simple system whose growth is determined by different and non-interdependent factors.

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(1) Education, Income, and Human Capital, edited by W.Lee Hansen, "American Economic Review", No.2, 1966, New York, 1970.

Meanwhile, the economy is a complex system all of whose components are interlinked, but the system itself is undergoing constant development with changes both in quantitative indices and in its very structure. This being so, attempts to estimate the contribution of any single factor, such as education, to overall economic growth while disregarding the tie-up with the remaining components of the system and with change in the general economic structure are to little avail.

The economic rôle of outlays on personnel training under the conditions of the scientific and technological revolution lies in the fact that they are an essential part of expenditure on changing the technical level and the structure of production and on raising the economy to a qualitatively higher level of development.

When there is a switch to the production of basically new items arising from the achievements of science, a change takes place in the entire production structure. Specific expenditure is required for research and design, for the launching of new materials and of machines to process them, and for the training of people with higher job qualifications. No basically new branch of industry can be pioneered without the development of a whole set of auxiliary and associated branches, those mainly involved being electronics, instrument-making, special chemicals, and so forth. There should thus be a significant structural change in industry as a whole, with the establishment of new branches and the re-organisation and sophistication of inter-branch links. At the same time, there should be extensive changes in the occupational and skill structure of the labour force and there will be a rise in the general standard of education. This applies not only to a new branch but to related branches of production as well. As a result, the whole of industry should advance a further step in the development of technology and job proficiency.

The establishment of objective relationships between capital investment in science, in new technology and in education enables specific conclusions to be reached about the pre-requisites for efficient employment of skilled personnel and about the connection between economic growth and job qualification.

Raising the proficiency of manpower resources cannot yield any significant economic effect where production is of a routine nature and the same items are put out year after year without any change in their quality specifications and production technology.

For coping with existing production technology and manufacturing a particular item, a certain skill standard is required; while a further improvement in that standard without any change in technology and product cannot improve labour productivity.

On the other hand, where production is dynamic and in step with technological progress, a constant rise in job qualification is essential to the adoption of ever newer products based on new methods and technology. And, naturally, the faster the pace of technological progress and the faster the adoption of new, technologically more advanced products, the faster the standard of job proficiency must rise.

A further aspect of job qualification also needs to be considered here as it is so closely bound up with technological progress, namely the aspect of instruction in the process of tackling complex scientific and technological assignments. The modern scientific and technological revolution has turned the process of economic development into a constant process of manpower self-education in the course of the assimilation of new methods and technology, the production of new and more complex types of product, and the organisation of new branches. This self-education, raising the level of job qualification, affects not only each individual engineer or worker but production bodies as a whole. They evolve such invaluable qualities as receptivity to new ideas and rapidity of orientation in complex technological issues. The higher the rate of technological process, the greater the effect of self-education will be. On the other hand, where production is on a routine basis with little or no change in the product and the methods involved, the process of self-education is ruled out.

Hence the close relationship between the rate of technological progress and the standard of personnel proficiency. The faster the qualitative changes in the development of the economy and the faster the rate of technological progress, the greater should be the potential reserve of knowledge and technological skills making for flexibility and creative mobility of manpower, the more should the standard of education of the work-force exceed the limited requirements of today's level of technology, and the greater the extent to which the standard of education should be geared to the future. The upshot of all this is

the change in the character of present-day job qualification.

2. A new type of job qualification

Scientific and technological progress engenders not only changes in the occupational and skill structure of labour but considerable improvements in the actual substance of job qualification. The advent of a basically new stage in the development of technology and production always results in such shifts.

The transition from the small-scale manufacturing stage of production to machine industry brought about, as we know, replacement of the workshop master craftsman with his great experience and his habits of manual work by the skilled worker with his experience and his habits of mechanical production. The essence of job qualification was considerably extended since the worker now had to be thoroughly familiar with machinery and to be able to regulate and adjust it, which further requires a certain minimum of specialist knowledge. Then in the development of the machine industry a number of separate periods can be distinguished which influenced both the general standard of job qualification and the change in the skill structure of manpower. In the metal-working industry, for instance, a particular stage in this regard was the transition in the 1920s and 1930s from universal to specialised machines incorporated in flow lines, which was the basis for the development of mass production. The introduction of specialised equipment and standardisation and the switch to mass production required a higher technical standard for most categories of workers. This was where foremen, technical inspectors, instrumentalists, model-builders, adjusters and other skilled workers in technical services came into their own. But on the whole there was a marked drop during that period in the relative numbers of skilled workers. This is due to a change in the forms of the organisation of production, which also substantially affect the skill structure of labour.

Such forms of mechanisation as the replacement of universal by specialised machines incorporated in the flow line, the replacement of power processing of metal by die-casting, and widespread application of conveyor systems in assembly work were used for extreme separation of the production process into elementary operations. The place of the skilled all-round worker was taken by the partial worker narrowly specialising in a strictly limited number of operations. This process

of splitting up the activity of the worker is somewhat reminescent of the organisation of labour in the manufactory period of the development of industry, with its partial workers. But the technological basis is of course quite different here: manual labour then prevailed, while now the brunt is borne by machines. Since jobs in mass production - as machine-tool operators and as assemblers - were mainly offered to workers who had undergone a short period of instruction and been promoted to the "semi-skilled" category, the general trend in structural changes during the 1920s and in the pre-war period was marked by a certain drop in the relative numbers of skilled workers.

It should be noted that at the same time there was an improvement in the essence of the job qualification of workers. The specialised equipment used in modern enterprises, in comparison with the old universal machines, requires of the worker less manual skill and personal art but greater precision in his work and greater technical literacy. The general technological standard of production is rising and mass production with its principle of inter-changeability of parts, calls for great precision in the machining of components.

We should accordingly not make blind use of the antiquated proficiency classification of workers. The separate categories of "semi-skilled workers" engaged on specialised machine-tools in modern enterprises are in a sense more highly skilled than the "skilled workers" in workshops of the semi-handicraft type.

Automation was a qualitatively new stage in the development of production technology and accordingly in the process of change in the skill structure. What basically distinguishes automation from various forms of mechanisation is the presence of a feedback system to which the function of direct control of the working process is switched. Under conditions of full or complex automation, man no longer takes a direct part in the actual working process. His functions are confined to the preparation of programmes and technological regimes for the automated unit, general observation and checking of its performance, together with regulation, adjustment and preventive repairs. In branches of industry where the process of complex automation of production is developing, the relative numbers of skilled workers are steadily rising.

Alongside the increase in the share of skilled workers, there is an equally steady decrease in the relative numbers of unskilled workers squeezed out of production. In individual enterprises with a high degree of automation, the skilled workers form an absolute majority of the work-force. Along with complex automation, however, there exist other partial or incomplete forms of automation where not the entire production cycle but only certain distinct operations are automated. The rapid development of automation in industry, beginning in the mid-1950s, mainly followed the partial, incomplete forms. Although features of automation in the form of automatic machine lines, automatic machines under programmed control, and the like, are fairly widely used in production, complex automation is still in its infancy. It is applied only in branches with an uninterrupted production cycle, namely chemicals, oil-refining, metallurgy, the food industry and the power industry. In the metal-working, electrical engineering, motor vehicle, aerospace, and other branches of industry, employing the bulk of industrial workers, the level of automation is relatively low and what is usually seen is various forms of mechanisation combined with partial automation.

In studying the effect of various forms of automation on change in the character of labour, Soviet economists analyse the shift in the correlation between operations requiring mainly intellectual or manual work. Thus for the operator in machine-building, working on a semi-automatic machine-tool, the functions involving mainly intellectual activity account for 50 per cent of his working time, the corresponding proportion for an automatic line operator being 68 per cent, and for an automatic line adjuster around 90 per cent. In metallurgy, for operators serving automated plant for continuous steel-teeming, such functions represent up to 88 per cent of working time. (1)

A rise in the level of automation is thus accompanied by "intellectualisation " of the activity of workers .

On the basis of surveys in various branches of United States industry in the 1960s, the following relationship was ascertained between the level of automation and the educational structure of personnel servicing automatic plant. (2) Although a high level of automation

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(1) Naucno-tehniceskij progress i proizvoditel 'nost' trude (Scientific and technological progress and labour productivity). Moscow, 1972, p.221

(2) E. Mueller, Technological Advance in an Expanding Economy: its impact on a cross-section of the labour force, Ann Arbor, 1969, p.162.

requires highly skilled manpower with mainly over twelve years of education, i.e. above secondary standard, semi-automatic systems mean that relatively less-skilled labour can be used.

Character of control system	Distribution of personnel by number of years of education (percentage)					
	Under 8 yrs.	8-11 years	12 years	Over 12 yrs.	No reply	Total
Logical control with feedback system	1	6	24	69	-	100
Automatic control without feedback	5	25	35	33	2	100
Semi-automatic control	16	40	31	12	1	100
Control by operator	10	40	33	15	2	100

Different forms of automation have differing effects on the skill structure of the work-force. Complex automation enables people to be wholly excluded from the production process, but partial forms of automation retain certain operations requiring direct worker participation. And rationalisation of the organisation of labour is directed towards making the operations as elementary and accessible as possible for rapidly instructed workers. It was just these processes, coming into their own in the United States in the 1950s, that prompted a number of US researchers investigating industry to conclude that automation resulted in a less skilled work-force. (1) In fact, this applies only to a few partial forms of automation whose adoption enables the owners of enterprises to

(1) New Views on Automation, New York, 1961.

effect large scale replacement of skilled machine-tool workers by hastily instructed operators classified as semi-skilled workers. This is particularly so in the case of workers loading transfer lines and removing the finished product.

A more complex issue is that of the job qualification of operators directly controlling automatic assembly units. Should they have a high skill rating or does push-button control so simplify all the functions of the operator that for this category it suffices to take on only briefly trained workers?

The key to the problem needs to be sought in a close study of the actual changes in production technology which in each of the instances are merged under the general term "automation".

Push-button control is used at various stages of mechanisation and automation, but the essence of the process differs. Under partial automation the functions of the operator may be reduced to a series of simple repetitive movements, in which case the panel operator is not the overall controller of the production process of the automat but a mere link in that process. His job is confined to receiving light or other signals and transmitting the corresponding orders to the unit.

Under complex automation conditions the rôle of the operator is immeasurably greater. From a mere appendage to the semi-automatic unit, he is transformed into the manager of the entire production process. Such functions call for a specialist with a broad background thoroughly abreast of all the intricacies of production.

Automation leads objectively in the course of its development to elimination of narrow partition of the labour process into elementary operations, with which the "partial" worker is associated. Complete automation is marked by the sort of broad-based skilled worker who is in essence a technical specialist.

The worker with a single trade - the narrow specialist - needs to be replaced by the worker with a number of trades, or the broad-based specialist. "The worker with a single trade is ill-equipped to meet the varied requirements for repairing and adjusting modern factory plant. Classification into trades becomes ever more complicated in the case of repair and adjustment assignments involving more than one speciality",

noted an ILO report on petroleum-refining and the petroleum industry.(1) With a continuous production process, the entire plant is linked up in a single functional complex, and a break in operation or failure of one of the component parts brings the entire complex to a halt. Hence the special requirements in terms of speedy repairs and elimination of malfunctioning. The trend is thus towards the worker with a number of trades who is at home in at least three areas, namely repairs to mechanical, electronic, and control and measuring equipment. This of course calls for considerable proficiency in each of those areas.

The process of combination of trades is not confined to repairing and adjusting. Of decisive importance is the fact that it is spreading to the functions of direct control of assembly units. The automation of production processes in the petroleum and petroleum-refining industry has freed operator workers from direct participation in the production process, leaving them in the basic function of observing the indications provided by instruments. This enabled them to combine the functions of the operator with those of the repair worker and the fitter. "In this situation the conception emerged of the highly skilled operator, a person with a high standard of proficiency in a number of trades who has not only been trained to perform the duties of the operator of any plant unit but is also capable of repairing and adjusting it. This is expected not only to ensure a saving of manpower but also to give the worker a certain emotional relief in that, first, his tasks will become more varied and, second, his interest in the smooth running of the machinery under his control will be based on a higher level of additional responsibility". (2)

The upshot of this has been that highly skilled workers combining the functions of operator and repair worker are regarded as technical specialists and included in the office worker category. All the privileges enjoyed by office workers and junior administrative personnel are extended to them and they are put on a fixed salary footing.

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(1) ILO. Petroleum Committee. Social Consequences of Structural and Technological Changes in the Petroleum Industry. Geneva, 1966, p.62

(2) op.cit.

Thus, as the modern scientific and technological revolution proceeds, many trades outstep the bounds of ordinary vocational training and call for special technical training to medium-level technical specialist standard. For the time being, this concerns only the most skilled workers chiefly in the rapidly developing branches of industry. But there can be no doubt that this process reflects an objective trend in development and will in the near future cover the basic trades in most branches.

The foregoing data provide evidence that in the course of scientific and technological progress the notions of "skilled", semi-skilled" and "unskilled" worker, as used in statistics, have in the last fifteen to twenty years undergone substantial changes. These changes are connected with the emergence of new trades and with the new substance of a number of traditional trades. A new character or type of job qualification can be said to have come into being. Let us consider its basic features:

(1) The essential feature of the new type of job qualification is breadth of qualifications and experience. In place of the worker narrowly specialising in the performance of a specific operation, we have the technologically educated specialist who is at home in a wide range of kindred specialities.

The broad background of the skilled worker is certainly not in itself a new quality. It was displayed way back by non-industrial master craftsmen in their field, namely that of handwork. The modern scientific and technical revolution raises the issue of the broad background of workers on an entirely new basis, that of sound technical knowledge.

Requirements regarding a broad background for the modern worker appear at first sight to be in contradiction with the trend that can be detected, beginning with the first steps in machine production: as production technology became more complex a process of specialisation went ahead and new specialities constantly emerged. In fact, what we are concerned with is not the universal tendency to divide labour but the forms of organisation of labour. Under the scientific and technological revolution the process of emergence of new occupations

is speeding up, but at the same time the organisation of production based on sub-division of occupations is proving less and less effective. Putting a person on one production line together with automatic machine-tools and other plant substantially limits possibilities of speeding up production processes. Therefore the more developed forms of automation entirely exclude people from the production process, leaving them only the functions of general supervision and technical maintenance.

Furthermore, extension of the configuration of job qualification involves the combination of various specialities that previously stood well apart from one another. Reference has been made above to instances of combination of the specialities of operator and repair worker for automated systems in the petroleum industry. Such processes also take place in other branches. This is due to the very character of present-day industrial production, which has come through a period of revolutionary leaps and shifts, with frequent and sometimes radical changes in methods of production and the constant introduction of new automation technology. The modern skilled worker has to assimilate this new technology on the go and take part in its improvement.

With the rapid advent of new and technologically more sophisticated types of product, the narrow specialisation of workers becomesa considerable obstacle to the operational redirecting of production to adoption of them. A broad skill background is now an important factor in hastening technological process and in making products more competitive.

Broadening of the skill background results in an increased proportion of "integral" specialities, which play a key part in many branches of industry and in other areas of the economy. Cases in point are the specialities of the computer operator and the programmer, of the specialist in repairs to electronic equipment, of the mechanic/repairman, and so forth.

(2) The second essential feature of the new type of job qualification is its dynamism. With the rapid change in and sophistication of production, there is a constant extension of the requisite volume of specialist knowledge for job qualification. As a result, in order merely to keep up to the mark as regards requirements for the speciality in question, the skilled worker must persistently study. Any shortfall here inevitably

produces a skill lag. According to the estimation of specialists, the proficiency level of a worker takes an average of ten years to become completely obsolete. However, in the most dynamic branches spearheading technological progress, such as the aerospace industry, computer production, etc., this lapse of time is considerably shorter.

The fact that the skill category is becoming ever more dynamic exerts a considerable influence on the whole system of the organisation of production. A direct consequence is the need for a permanent system of in-service training for workers. In the circumstances of the scientific and technological revolution, the training process is becoming one of the most important components of the production process.

(3) The above features of the new type of job qualification can be put into practice only on the basis of a fundamental general education for young workers in general schools. The requisite standard of general education for modern industrial specialities is rapidly rising and is now approximately at the level of complete secondary education. Below this standard, it is impossible to come to terms with a broad-based speciality. At the same time, this standard is becoming a jumping-off ground for further occupational advance without which skills are rapidly outdated. Although vocational training was previously based mainly on the acquisition of practical skills and could be separated from general education, the situation now is that general education is a component and the basis of vocational training. This then is the third essential feature of the new type of job qualification prompted by the scientific and technological revolution - the need for a high standard of general education.

The following figures give an idea of the improved standard of the general education of workers in the USSR: for every 1,000 workers in 1959, there were 396 with secondary (complete and incomplete) and higher education, the corresponding figures for 1970 and 1976 being 586 and 715 respectively. (1)

In connection with the new type of job qualification prompted by the scientific and technological revolution, a new conception of vocational training is also emerging. There are a number of features to this conception:

(1) USSR Central Statistical Office. Narodnoe hozjajstvo SSSR v 1975 g. The national economy of the USSR in 1975), p. 38.

(1) Vocational training can no longer be regarded as something distinct from general education. Secondary schooling is essential for providing the corresponding theoretical basis for vocational instruction.

(2) Replacement of narrow specialisation by versatile training in a broad range of allied specialities, and the fostering of a broad technological outlook.

(3) With the rapid change in the scope of trades, regular re-training should, instead of remaining an exceptional measure, be made a permanent system covering all personnel.

In the USSR the main channel at present for training skilled workers is the vocational schools. The numbers attending them went up from 1,064,000 in 1961 to 3,081,000 in 1976. (1) Unification of general and vocation education is effected by means of secondary vocational schools which, alongside instruction in a trade, offer a complete secondary curriculum leading to the official school-leaving certificate. Out of the total 1976 enrolment of 3,081,000 pupils in vocational schools, secondary vocational establishments accounted for 1,191,000.(2) For young workers without secondary education, a network of general night schools is provided.

The integral combination of a high level of attainment in fundamental general subjects with the acquisition of vocational knowledge and know-how makes for highly skilled workers. Thus in vocational secondary schools offering a three to four year course, workers are trained in such complex trades as automatic plant repairer, adjuster of automatic machine-tools, electrical motor mechanic, electronics mechanic, instrument control man (in the chemical industry), and so on.

Another important type of institution training highly skilled workers in the USSR is the two-year technical school, attended by people with complete secondary education. The fact that a high standard of general education is required may be explained by the more complex duties and greater responsibility of the modern worker. For instance, the skilled worker serving a transfer line must know the entire technological cycle, the equipment used, the component specifications, and the properties of

(1) op. cit., p. 555

(2) Ibid.

the material in process. He must be able to make rapid mathematical calculations, applying the laws of physics and be familiar with electrical engineering, hydraulics and pneumatics. His duties include supervisory work, with the adjustment and regulation of the transfer line. (1)

In the United States the rate of development of the system of vocational education in specialised skills for industry is attested by the following figures: in 1950 the number of people receiving such education was 805,000, while in 1960 total attendance was 938,000, rising to 2,702,000 in 1973. The total anticipated for 1978 by the vocational education bureau of the Department of Health, Education and Welfare was 4,300,000.(2)

The extension of vocational education in the past ten years h been particularly rapid. Alongside rapid quantitative growth, there have also been important qualitative changes in the system of vocational education. Relatively fewer workers are trained by means of the system of short courses for adults, and most of them learn a trade in vocational secondary schools and in higher-level institutions. This is shown by the following official figures of the National Educational Statistics Centre in the United States:

Education of workers for industry[x]
(In thousands of persons)

	1966		1973	
Total	1 269	100%	2 702	100 %
In secondary vocational schools	319	25	1 134	42
In post-secondary schools	116	9	345	13
Through the adult education system	804	63	1 223	45
Other forms of education	30	3	-	-

[x] Digest of Educational statistics. Washington, 1974, p.43.

(1) S.Y. Batyshev. Formirovanie kvalificirovannyh rabocih kadrov v SSSR (The training of skilled workers in the USSR) Moscow, 1974.

(2) Trends in Vocational Education, Washington, 1974, p.11

An ever greater proportion of pupils attend vocational schools providing complete secondary education. At the same time, in order to produce highly skilled workers in a number of special lines, fixed full-time study lasting several years is necessary in special technical schools after completion of secondary education. Thus the raising of the proficiency standard of workers in new trades to the level of medium-range technical personnel requires a degree of harmonisation in the forms of instruction provided for these categories.

Important changes are taking place in the level and substance of job qualification not only of workers and technicians but also of specialists with higher education. When assessing the development of the higher education system, attention was until recently focused on the quantitative aspect i.e. the number of students and graduates in a particular field of specialisation. What is much less clear is the quality aspect or the problem of the standard of specialist education. This can mainly be explained by the lack of reliable indices high-lighting changes in education quality. Meanwhile the quality aspect in the education of key personnel is coming to the fore. Many intermediary engineers are unable to take over from some particularly qualified specialists when it comes to the technical materialisation of scientific discoveries and to the revolutionary transformation of production.

In the process of economic, scientific and technological progress, the area of routine in production is constantly tending to shrink, and periodical changes in methods and technology and in the nature of the end product are becoming increasingly intensive. In this connection, there is an increased creative element in the work of the engineer. Hence the need for all engineers qualifying nowadays to be highly proficient top-class specialists. Present-day requirements regarding the job qualification of the engineer fall into three main divisions:

(1) The young specialist should be trained as a creative worker possessing both a thorough knowledge of modern technology and the requisite skills for independent design and research work.

(2) He should be abreast of the latest methods and technology used in his area of activity.

(3) He should have a grounding in a wide range of disciplines, which is essential to success in innovative engineering design and the elaboration of new technological processes.

Looking into the changing requirements as to the kind of education engineers should receive and into practical recommendations made in this respect (1), we can first spot the need for the earliest possible familiarisation of engineering students with practical drawing and design work, which is regarded as an integral part of the course of study. The term "design work" is taken here in a broad sense : not just as the elaboration of new machine or equipment systems but, in general, as the practical application of new scientific principles and methods in the production process and in the creation of new goods and services. Thus the job qualification of the engineer must be approached from the standpoint of his new place in the process of social production - as the central link between the realm of scientific research and that of mass production.

The development of the scientific and technological revolution presents engineers with new complex tasks in areas extending far beyond the bounds of narrow technical considerations. Modern engineering includes the elaboration of complex information systems, transportation systems, national power systems, and so forth. The aggravation of ecological problems, highlighting issues of environmental protection, city planning, and the like, present engineers with extremely complex tasks in the social field, such as the elaboration of systems to counter problems like air, water and soil pollution, noise, traffic congestion, and over population. Engineering activity is thus beginning to address itself to increasingly complex issues demanding close co-operation with the representatives of such diverse brances of science as physics, biology, medicine, sociology and psychology. Hence new requirements regarding the fundamental scientific education of engineers. Thus, in place of a utilitarian and narrowly specialised approach to physics, the need has arisen to give students broader conceptions of the development of this science, together with its unsolved problems and development prospects. The new topical issues facing engineering -

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(1) Future Directions for Engineering Education. Washington, 1974

concerning ecology, quality of life, etc. - call for inclusion in the curriculum of courses throwing light on the essential tie-up of physical and medico-biological problems, together with problems of information and, the assessment of engineering projects from the standpoint of their social consequences.

3. The demand for and employment of highly qualified personnel

The early 1970s were marked by a certain upheaval in the development of supply and demand regarding highly qualified manpower resources in the industrialised capitalist countries. Although the previous decade was on the whole marked by a shortage of scientific and technical specialists, the situation now is that it is impossible to employ all the available specialist manpower and all new graduates.

In the United States, according to the conclusions of the Carnegie Commission which looked into the situation regarding the development of higher education in the country, the real problem for the current decade is the job placement of over 25 per cent of the total number of college graduates - or 2.6 out of 9.6 million people. (1) The Commission's report also notes that among college graduates with jobs, 32.4 per cent cannot make use of the education they have received and are employed outside their special fields as factory workers and business and office employees. (2) According to forecasts up to 1985 supplied by United States Governmental organisations, the excess of supply over demand for most specialities (physics, mathematics, biology, teaching, arts subjects) will persist and may even increase.

In the United Kingdom, according to the estimations of the Institution of Mechanical Engineers, there is a surplus of engineers. (3) In the Federal Republic of Germany, the Federal Ministry of Scientific Research forecasts that the real demand for specialists with higher education in 1980 will be 342,000 as against a matching manpower availability of 385,000. The Federal Republic is at present short of specialists in medicine, technology and the natural sciences, but at

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(1) College Graduates and Jobs, Hightstown, 1973, p.3

(2) Monthly Labor Review, No.2, 1973 pp.41-50

(3) British Journal of Industrial Relations, No.1, 1973, p.123

the same time has too many in arts subjects. In the event of extension of engineering education, however, the representatives of the major industrial companies hold the view that there will be an over-production of specialists in the field of technology. (1)

This has given rise to the serious question of the objective demand for highly skilled specialists and of the factors determining the real demand for them. The complexity of the question lies in the fact that there is a difference between the social and economic requirements of society regarding specialists and the actual demand for them. This demand, in terms of the number of jobs for specialists, is limited by the general level of social and economic development and by the basic priorities of economic and of science and technology policy. The requirements of society stem from the necessity to satisfy as fully as possible all the economic, social and cultural needs of the population. This means that society has an objective interest in increasing the numbers of doctors, teachers, engineers, economists, scientists and workers in culture and art, and in securing access for all members of society to higher forms of education.

It may be as well to pause awhile on the social demand for education. The foregoing tendency for the level of proficiency and education of manpower resources to rise proceeds under market conditions through the squeezing-out of less skilled workers and their replacement by more qualified people. As a result, the requisite standard of education for remaining in or joining existing work-forces is rising. This standard may be regarded as the lower limit of the social demand for education.

But the social demand for education hinges on many factors, among which a considerable rôle is played both by the aspirations of individual classes and social groups and by the overall development trend. The ever greater social importance of the work of highly skilled specialists, as reflected in their income growth, has prompted the widespread conviction that expenditure on providing one's children with higher education is the most effective form of investment and a means of throwing open the "way up". Hence the endeavour of parents to secure for them a higher standard of education than that they themselves received.

(1) Handelsblatt, 6 January, 1973.

These processes take place against a back-drop of a generally increased desire for education prompted by the vast successes of modern science and technology. As a result, the yearning for knowledge is being transformed, with the development of the scientific and technological revolution, into one of the essential demands of the broadest sectors of the population. The rise in the general level of knowledge and of the cultural assets accumulated by man is matched by a rise in the social demand for education.

What is the upper limit of this demand? It is obviously associated with the possibility of bringing out the potential capacities of each individual and achieving his all-round development. It follows then that this limit is mobile: as the general level of knowledge rises, potential capacities can be realised at an ever higher level. From this stand-point, the possibilities for developing the personality are boundless. The limitations are set by actual social and economic conditions. The degree of satisfaction of the social demand for education depends to a large extent on the social and political system of the country in question and on the level and pace of its economic development.

Under a planned socialist economy, the State endeavours to take account of the social demand for education and the requirements of society regarding highly skilled specialists when drawing up and implementing socio-economi plans for meeting them, to the extent permitted by available resources. Of great importance here is the planned development of the education system, with special reference to higher education. In these circumstances, it becomes possible to co-ordinate economic development and specialist education plans, which means a job for every young specialist.

In a free market economy the supply of and demand for highly skilled personnel will, despite State intervention, fall in with market laws. The cyclical character of economic development pre-determines the sharp fluctuation of this demand. A basic regulator between supply and demand in the market for specialists is provided by the reaction

of young people to the emerging imbalances. Where the demand for specialists with higher education or for specific occupations requiring higher education exceeds supply, new vacancies come up and rates of pay for this employment category rise faster than the national average. The result is a greater influx of university entrants into the corresponding faculties. Where the demand for specialists lags behind the increased market supply of highly skilled manpower, university graduates are unable to find work in their special lines and the number of higher education entrants takes a dip.

Research by United States specialists - in particular R. Freeman, a Harvard professor who constructed a dynamic model of change in the number of students and output of specialists in such fields as engineering and physics (1) - has shown that among economic factors influencing the choice of a particular occupation, a decisive part is played not by the level of pay but by the likelihood of finding, on graduation, the kind of work for which one has studied. It follows from R. Freeman's model that the flow of entrants into a particular faculty and the output of young specialists must be cyclical.

The process whereby supply and demand even out in the market for highly skilled personnel, with a considerable time lag, inevitably leads to a periodical shortage or surplus of specialists in relation to the number of jobs available for them. The absence of purposeful long-term plans in the area of manpower training, based on the real needs of society regarding specialists, gives rise to imbalances in the structure of specialist education.

If one can keep clear of cyclical fluctuations in supply and demand, the total employment of specialists is determined by fundamental economic development factors, i.e. the established economic structure and the rate of economic growth. As scientific and technological progress moves on and the general level of economic development rises, the structure of the economy changes. This is reflected, in particular, in the increased rôle of the non-material production sector, more

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(1) R. Freeman, The Market for College-Trained Manpower, Cambridge, 1971.

commonly referred to as the general service sector. A new sector of specialised services in fact arises in which a decisive part is beginning to be played by highly skilled personnel. This is attested by the distribution in it of an occupational group internationally classified as "professionals", made up of key scientific and technical manpower, teachers, doctors, and medium-level personnel in engineering and in medicine, together with people in the free professions. A feature of this group is the high standard of general and specialist education of its members: most have higher education and the remainder secondary specialist.

As can be seen from Table 6, a considerable proportion of specialists - from 40 to 60 per cent of the total - is employed in the education and medical branches. Extension of such branches is one of the most important factors in increased demand for highly skilled personnel. Another area of activity accounting for a sizeable proportion of specialists is manufacturing industry, particularly those of its branches that are spearheading scientific and technological progress.

Thus, in order to secure a high level of specialist saturation, the structure of the economy must be consistent with a high level of scientific, technological and economic development. There should be a definite link between the relative number of specialists in the economically active population and the economic development index.

This link could be defined as follows. Let us take as an indicator of the economic development level the per capita GDP figures in United Nations statistics. (1) Let us calculate the proportion of specialists from data supplied in the Yearbook of Labour Statistics.(2) Since in no case does the information for a particular year cover anything like all the countries, data for differing years had to be used. For those years the matching per capita GDP figures are given in 1974 dollars. (See Table 7)

It can be seen from Table 7 that the tie-up between the compared indices is relatively slight : the linear correlation coefficient amounts to + 0.441. The unexpectedly low correlation coefficient can

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(1) Yearbook of National Accounts Statistics, Vol. III, New York, 1975

(2) Yearbook of Labour Statistics, 1976

Table 6. Distribution of specialists per branch of the economy (%) (data for late 1960s) (1)

Country	All specialists	Employed in material production branch	Employed in education branch	Employed in public health service	Employed in remaining areas
USA	100	25	31	18	26
Canada	100	21	32	21	26
United Kingdom	100	28	26	22	24
France	100	32	24	15	29
Germany (Fed. Rep.)	100	33	21	19	27
Japan	100	13	38	23	26

(1) Statistics of the Occupational and Educational Structure of the Labour Force in 53 countries, OECD, Paris, 1969.

be explained by the fact that the proportion of specialists at any particular time depends not only on the level of economic development attained but also on a number of other essential factors, prominent among which is the economic growth rate. The demand for highly skilled manpower depends both on the established economic structure and on how fast the structure changes.

In industry the creation of new jobs for specialists is limited by the volume of capital investment in the extension of production (the extensive factor) and investment in improvement of the technological basis of production (the intensive factor). The faster the introduction of new forms of production technology and new technological processes, and the faster the nature of the product is renewed, the greater will be the requirements in terms of the proficiency standards of industrial manpower the higher should be the relative numbers of engineering and technology workers among industrial employees. The speeding-up of technological progress produces a situation in which intra- and inter-branch relations become ever more complex and dynamic, there is a surge in the flow of technical and economic information, and the demand grows for specialists in planning, organisation and management, systems analysis and the like. Since there is a close tie-up between the scale of investment and the existing rate of economic development, the demand for specialists in industry depends to a considerable extent on that rate.

Since the economic return on investment in development of the technological basis of production does not materialise immediately but after an interval of a few years, the creation of new industrial jobs for specialists is to a significant extent connected with expected production growth rates several years ahead. If high future growth rates are expected, there is a rise in current investment activity and new jobs are provided for specialists. If on the other hand low rates are expected, the demand for specialists drops.

In the research and development field, the creation of jobs for specialists is limited by the total volume of expenditure on research and development and by the magnitude of unit expenditure - reckonedper scientist or engineer employed in science. Expenditure

on science per scientist or engineer has a constant tendency to rise with the increase in value of scientific equipment and higher pay for scientific and technical manpower. The total volume of expenditure on research and development is in turn limited by : (a) the level of economic development attained; and (b) the conjectured efficacity of such expenditure in the future.

What is involved here is not the aims of science and technology policy, which may be fairly far removed from economic issues (e.g. the development of research for military purposes), but the feedback between the development of science and the economy. Science is financed out of the economy and the greater the economic efficiency of expenditure on science, the greater will be the capacity for investment in research.

Since expenditure on science takes longer to produce a return than in the case of industrial investment, the number of jobs for specialists in the research field hinges, to a greater extent than in industry, on the expected economic growth rate. With regard to teachers, the number of jobs is determined by the total volume of State and private expenditure on education.

Thus the employment of specialists is limited, first, by the level of economic development attained, which determines the structure of the economy and the occupational structure of the labour force, and, second, by the investment activity of 'entrepreneurs' and by State budgetary policy, geared to expected economic development rates for the future. This being so, both investment activity and budgetary allocation policy are strongly influenced by the prior rate of economic growth. As a result, the demand for highly qualified specialists at a given time is determined both by the existing level of economic development and by the projected economic growth rate.

The need arises to introduce some combined indicator denoting both sides of this process : statics (level attained) and dynamics (growth rate). In a general form the relationship can be formulated thus:

$$Yw = F(P,r)$$

where Y : is the share of specialists in the economically active population;

P : the per capita gross domestic product ($\frac{GDP}{p.c.}$) :

r : the annual percentage growth rate $\frac{GDP}{p.c.}$

w : the ratio of the level of pay for specialists to the countrywide pay average.

Specifying this relationship, we shall obtain:

$$Yw = k\ P(1 + \frac{r}{100})^n$$

where k : is the linkage factor, and

n : the number of years.

The existing demand for specialists is determined from the expected economic development level, based on the current growth rate. Assuming that the amortisation period for investment in creating jobs for specialists is five to ten years, we may simplify the formula thus:

$$Yw = k\ P(1 + \frac{r}{10})$$

To check the relationship obtained, let us make use of United Nations statistics on per capita gross domestic product (see Table 7) and on the rate of change of this index for the previous year. (see Table 8.)

The coefficient of linear correlation between $P(1 + \frac{r}{10})$ and Y amounts to + 0.874, and the coefficient of determination + 0.764. The regression equation takes this form :

$$y = 2.963 + 1.507x$$

The economic development level and the rate of change in it are really the chief factors in the demand for highly qualified personnel. Of particular significance here is the rate of change. If the demand for highly qualified personnel were determined by the level of economic development alone, it would constantly rise and would be secure from sharp fluctuations and, all the more so, from declines. The level of economic development is not as a rule subject to sharp declines. On the other hand, its growth rate is extremely unstable and any decrease in the rate is immediately reflected in the market for skilled manpower.

Table 7. Comparison of the economic development level and the proportion of specialists

Country	Year	GDP per capita ($ thousands)	Specialists as % of economically active population
Sweden	1974	6,87	22,4
USA	1974	6,67	13,9
Canada	1974	6,46	14,3
Australia	1971	5,96	10,1
Norway	1974	5,83	15,8
Germany (Fed. Rep.)	1970	5,75	9,8
Denmark	1970	5,47	12,2
Netherlands	1971	4,66	13,3
Belgium	1970	4,54	11,1
Japan	1974	4,15	7,8
France	1968	3,89	11,4
Austria	1971	3,74	8,7
United Kingdom	1971	3,13	11,1
Venezuela	1974	2,54	8,6
Italy	1971	2,44	7,3
Spain	1970	1,96	5,5
Greece	1971	1,92	5,7
Mexico	1974	1,12	6,2
Argentina	1970	1,00	7,5
Brazil	1970	0,61	4,8
Iran	1966	0,52	2,7
Philippines	1974	0,36	5,3
Pakistan	1974	0,13	2,1
India	1971	0,12	2,7
Indonesia	1971	0,09	2,2

Table 8. Combined indicator: offers of employment as a function of the level of economic development and the rate of growth.

Country	GDP p.c. ($ thousands)	r (as a %)	P (1 + r/10) ($ thousands)	y
Sweden	6,87	3,8	9,49	22,4
USA	6,67	- 2,3	5,13	13,9
Canada	6,46	1,7	7,56	14,3
Australia	5,96	2,0	7,15	10,1
Norway	5,83	3,6	7,92	15,8
Germany (Fed. Rep.)	5,75	2,0	6,90	9,8
Denmark	5,47	2,0	6,57	12,2
Netherlands	4,66	3,0	6,05	13,3
Belgium	4,54	6,4	7,45	11,1
Japan	4,15	- 2,4	3,16	7,8
France	3,89	3,5	5,25	11,4
Austria	3,74	4,0	5,23	8,7
United Kingdom	3,13	1,0	3,44	11,1
Venezuela	2,54	1,0	2,79	8,6
Italy	2,44	1,0	2,68	7,3
Spain	1,96	5,3	2,99	5,5
Greece	1,92	7,0	3,27	5,7
Mexico	1,12	2,0	1,34	6,2
Argentina	1,00	4,0	1,40	7,5
Brazil	0,61	6,0	0,97	4,8
Iran	0,52	9,0	0,99	2,7
Philippines	0,36	2,0	0,42	5,3
Pakistan	0,13	0,0	0,13	2,1
India	0,12	0,0	0,12	2,7
Indonesia	0,09	4,0	0,13	2,2

The figures for the proportion of specialists do not in the case of most countries fully coincide with the straight line of the regression equation. It is merely the median line in relation to the points denoting the position of individual countries. But we are also interested precisely in departures from the median line. This is where the different degrees of saturation of the economy with specialist personnel show up, together with the national particularities of the countries, their specific economic structures, and so on. International comparisons are also dangerous in that the development proportions of one country should not be mechanically transposed to another. In this case, however, we are taking an average general tendency for many countries where national particularities are considerably evened out and general patterns emerge. Departures from the median line represented by the regression equation can accordingly to a certain extent be regarded as the real indicator of a surplus or shortage of specialist personnel on the labour market at a given time and in a given country in relation to the mean level. (see Table 9)

As can be seen from Table 9, there is a certain "surplus" of specialists in a number of industrialised countries. This corresponds to the real correlation of supply and demand on the market for highly skilled manpower in those countries. In fact, however, there is no such "surplus" if the problem is approached not from the standpoint of demand on the labour market but from that of meeting real social and economic needs in respect of medical services, education, extension of the system of children's institutions, a higher cultural level, and so forth. Let us take the example of just one indicator - the number of doctors per 100,000 inhabitants in different countries. Table 10 shows the corresponding 1971 figures of the Organisation for Economic Co-operation and Development set against per capita gross domestic product. (1)

It would be logical to suppose that the higher the level of economic development of a country, the more resources it can expend

(1) Etudes économiques de l'OCDE - Suède, Juin 1975, p.79

Table 9. Indicators of a surplus or shortage of specialist personnel

Country	Year	Share of specialists in economically active population (%)	
		Actual	Calculated from regression equation
Sweden	1974	22,4	17,3
USA	1974	13,9	10,7
Canada	1974	14,3	14,3
Australia	1971	10,1	13,7
Norway	1974	15,8	14,9
Germany (Fed.Rep.)	1970	9,8	13,3
Denmark	1971	13,3	12,8
Netherlands	1971	13,3	12,1
Belgium	1970	11,1	14,1
Japan	1974	7,8	7,7
France	1968	11,4	10,9
Austria	1971	8,7	10,8
United Kingdom	1971	7,5	7,2
Venezuela	1974	7,3	7,0
Italy	1971	7,3	7,0
Spain	1970	5,5	7,5
Greece	1971	5,7	7,9
Mexico	1974	6,2	5,0
Argentina	1970	7,5	5,1
Brazil	1970	4,8	4,4
Iran	1966	2,7	4,4
Philippines	1974	5,3	3,6
Pakistan	1974	2,1	3,1
India	1972	2,2	3,0
Indonesia	1971	2,7	3,0

Table 10. Comparison between two indicators: number of doctors in GDP.

Country	Number of doctors per 100,000 inhabitants (1971)		Per capita GDP in dollars (1973)	
	Quantity	Order	Value	Order
Germany (Fed. Rep.)	125	17	4900	8,5
Australia	187	1	3550	17,0
Austria	160	6	4650	12,0
Belgium	150	8	5410	6,0
Canada	141	11	5460	5,0
Denmark	111	20	3720	16,0
Spain	138	13	4900	8,5
USA	171	3	5610	4,0
Finland	167	4,5	1790	21,0
France	144	10	4870	10,0
Greece	109	21	2130	20,0
Ireland	183	2	2510	19,0
Iceland	115	19	3760	15,0
Italy	107	22	5200	7,0
Japan	131	15	4410	13,0
Luxemburg	116	18	4080	14,0
Norway	145	9	4780	11,0
New Zealand	98	23	1250	23,0
Netherlands	139	12	1750	22,0
Portugal	136	14	6140	3,0
United Kingdom	45	24	540	24,0
Sweden	157	7	6170	2,0
Switzerland	129	16	3100	18,0
Turkey	167	4,5	6190	1,0

on health and other social needs and the higher should be, in particular, the index of the number of doctors in relation to the total population figure. The data given above prove, however, that the positive correlation between the level of economic development and the extent of medical care coverage for the public is extremely slight. The coefficient of correlation of orders is + 0.355. In terms of the number of doctors per 100,000 inhabitants, the leading positions are occupied by Austria and Italy, whose gross domestic product figures are several times lower than in the case of such countries as the United States and Sweden. At the same time, the latter countries far outstrip Austria and Italy when it comes to the provision of medical services for the public.

The field of health is no exception. A similar situation is encountered in education, children's institutions, culture, environmental protection and many other social areas not enjoying priority in the matter of public spending.

Meanwhile, as the scientific and technological revolution proceeds, the question of long-term policy aims and priorities in science and technology and in social and economic affairs is gaining in importance. The world can no longer let itself gallop on the tiger of technology without placing upon it the curb of sound social and economic aims; such was the conclusion of an expert meeting of the Organisation for Economic Co-operation and Development. (1)

Utilisation of the scientific and technological revolution aims not at the establishment of some new world of technology, both strange and hostile to man, but at all-round development of man's abilities and potentialities. When it comes to long-term aims, the problem of the various economic development alternatives involves not just the choice of a particular State policy deciding on priority areas for public spending, but much more cardinal and fundamental issues. What we are concerned with here is the actual future trend of the character of modern society in the course of the scientific and technological revolution. Will the trend take us further along the path of the fetishisation of "thing" values - a path typified by the "consumer society" - or will material production be subordinated to other, higher

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(1) The OECD observer, December 1973, p.29.

values? The question is that of a cardinal reappraisal of values and a new conception of the quality of life including, alongside satisfaction of material needs, satisfaction and development of the social and spiritual needs of society, and extending to the problem of the biosphere in the whole complexity of its tie-up with the scientific and technological revolution. It seems then that without any such reappraisal, there can be no solution to most of the new problems facing present-day civilisation. Hence the need for a change in policy priorities with regard to science and technology and to socio-economic matters, and for a re-allocation of resources so as to come to grips with urgent social problems.

The question arises of the effect of such a re-allocation on the employment level, particularly the employment of highly skilled manpower. This matter is debated in scientific circles and State organisations in many countries.

Let us consider, for instance, the question of the possible transfer of funds earmarked for military expenditure to the area of social needs. In the opinion of a number of authors, such a transfer should bring about various changes in employment in different branches of the economy as a result of the altered structure of demand of the military production sector and the sector of health and social security. In particular, a fall in employment would be expected in the manufacturing industry. (1) This view is based on the contention that where there is a substantial transfer of funds from the military to the civilian sector, the demand structure of the civilian sector will not change, that is, there will simply be an increase in the number of doctors, nurses, subsidiary personnel, and so on, without any change in the level of material provision for health (capital expenditure per employee will not significantly alter). This is the basically vulnerable part of the calculation. A transfer of funds from one sector of the economy to another (in the case of really large transfers affecting the structure of social production) leads to a change in the structure of demand in those sectors and to a change in the amount of capital available per worker in them. The field of public health, in particular, requires no

(1) The Structure of the U.S. Economy in 1980 and 1985, Washington, 1975.

less sophisticated electronic equipment than the military sector. The whole point is that up to now public health has, in a number of countries, been on short rations in terms of material provision. Therefore the existing tenfold discrepancy in the structure of ultimate demand for electronic products is, to a considerable extent, the outcome of the priority enjoyed by military industry over the civilian sectors. A change in priorities will give rise not to a dramatic cutback in employment in the electronics industry (or in manufacturing industry as a whole), but to a switch of that branch from military to civilian production.

As established earlier, the distribution of research resources by branch of industry also does much to predetermine the distribution of engineers and technicians employed in research, in management and directly in the production process. If there is no change in the distribution of expenditure on research and development, a switch in capital investment from science-intensive branches to less science-intensive branches will cut the number of jobs for scientific and technical specialists.(1)

At the same time, the reasoning behind forecasts is that since research and design work is considerably less developed in the civilian branches, there will be a cutback in scientific and technical manpower. However, an estimate of the effect on the employment level of a switch in investment from military to civilian industry cannot be restricted to the existing level of science-intensiveness of production within the branches in question. What must also be borne in mind is the structural effect, the change in inter-branch links, and the emergence of new types of production and spheres of application of labour and capital as it becomes possible to concentrate resources on many vital issues of the present day. All this provides new areas of application for the work of engineers, scientists and researchers.

Therefore a change in the priorities and aims of science and technology policy and a re-allocation of resources cannot lead to a cutback in jobs for scientific and technical specialists, not to mention specialists in the fields of public health, education and culture. On the contrary, the pressing problems of today cry out for an increase in the scientific and cultural potential of society.

(1) Scientific Manpower, A Dilemma for Graduate Education, S. Brown and B. Schwartz, Cambridge-London, 1971, pp.52-57.

4. Conclusion

Present-day scientific and technological progress is impossible without a constant rise in the proficiency level of the labour force and a change in its occupational and skill structure. A new type of job qualification is being composed, the essential features of which are: a broad background; the need for constant extension and renewal of scientific knowledge; and a high standard of general education. Modern industrial production, with its rapidly changing technical basis and technology and with the continual adoption of new, science-intensive products, calls for extension of the occupational background and for a greater amount of special and general knowledge. As a result, the education process is becoming one of the most important components of the production process.

A decisive effect on change in the occupational and skill structure of the labour force is exerted by two basic trends of scientific and technological progress: (i) the process of "cybernetization" associated with the widespread advent of computerised control and management of production in all spheres of the economy; (ii) the increased scale of research and development in production, which hastens the process of structural changes in the economy and results in new branches and types of production involving fundamentally new products. Production is becoming increasingly science-intensive.

As shown by numberical analysis, the amount of machinery available to labour (closely connected with the level of automation) and the level of science-intensiveness of production go a considerable way towards determining the structure of the industrial work-force, particularly the relative significance of such key categories as scientists and engineering and technological manpower.

The establishment of an objective relationship between the level of machinery available to production, its degree of science-intensiveness and the job qualification of manpower resources enables us to define the necessary conditions for the effective utilisation of skilled manpower and to recognise a connection between economic development and job qualification. Making a work-force more proficient cannot yield any significant economic effect where production is of a routine character

and there is no change in the quality characteristics of the product and in production technology. On the other hand, with dynamic production a constant rise in job qualification is a pre-requisite for technological progress.

Investigation of the problem of the employment of highly qualified specialists has shown that demand for them is ultimately determined by the level and rate of economic development and by the priorities of socio-economic and of science and technology policy. The higher the rate of economic development, closely tied in with scientific and technological progress, and the greater the extent to which economic and science and technology policy is directed towards satisfaction of the social needs of the population, the more scope there will be for making effective use of highly qualified specialists.